Imaging the human auditory system at ultrahigh magnetic fields

Knowledge Valorisation

Etymological origin of the word "valorisation" comes from the Late Latin *valorem*, which means "value" or "worth". Therefore the term "knowledge valorisation" can be understood as assessing the value of the knowledge generated in this thesis. However, according to report of the Netherlands National Valorisation Committee, Indicators for valorisation (2011, page 8), knowledge valorisation is defined as "the process of creating value from knowledge, by making knowledge suitable and/or available for social (and/or economic) use and by making it suitable for translation into competing products, services, processes and new activities". Therefore, an additional meaning is given onto this term as *not only assessing but also highlighting how the knowledge generated in this thesis is made available to public*. As a modern scientist, addressing both meanings of the term in this section is straightforward. In what follows, I am going to list different valorization methods used in this thesis.

However, before detailing the valorization methods, a brief summary of the content would orient the reader. This thesis is about one of the fundamental sensory systems: audition (hearing). In order to treat auditory impairments, or enhance the natural human hearing capabilities, we need to understand how human hearing works. In order to understand how the human hearing works, we need to study the hearing system as a whole. Including the ear, the cortex and everything in between (the subcortex). The main aim of this thesis is to use one of the cutting edge biomedical technologies, ultra-high field MRI, to study the human auditory system as a whole. This endeavor is still a long and challenging journey however many useful products already came into fruition.

Maybe the most straightforward valorisation effort in any scientific experiment is making the data available to public.Any scientific study can gain significant value by not only publishing articles and conference contributions but also making the data available Famously, Einstein could improve his relativity theory thanks to the data that was available to him. It was not possible for him to make all the measurements himself while also developing the theoretical framework. As a domain-specific example,

the BigBrain dataset is one of the example publicly available dataset that is being used in many studies. This thesis would certainly be less complete without being able access the data provided in the BigBrain project. To this end, I have spent significant effort for curating and publicly sharing the majority of the datasets acquired for my thesis (see Figure V1, V2, V3).

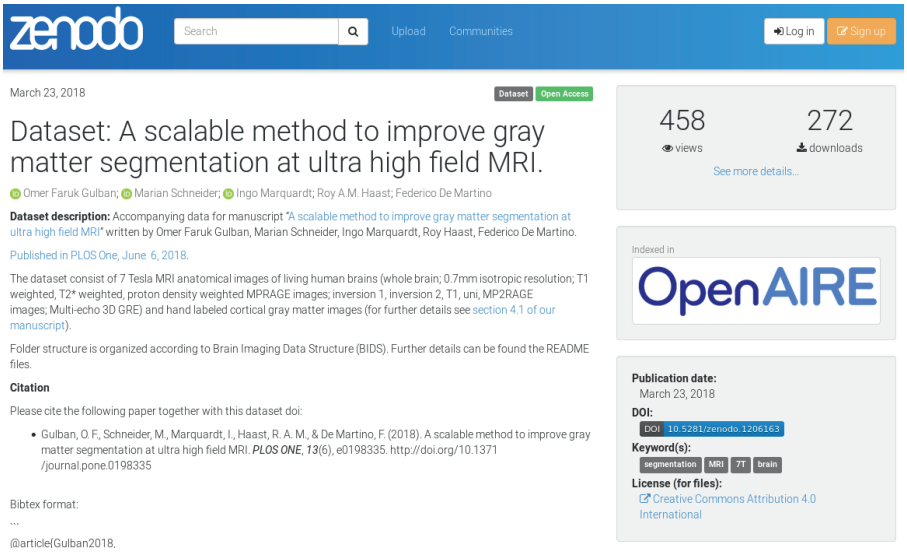

FIGURE V1: Gulban, O. F., Schneider, M., Marquardt, I., Haast, R. A. M., De Martino, F. (2018). Dataset: A scalable method to improve gray matter segmentation at ultra high field MRI. (Version v2.0) [Data set]. Zenodo. http://doi.org/10.5281/zenodo.1206163

These datasets will be helpful to replicate the findings presented in this thesis, validate the new results presented by other researchers, and most likely inspire multitude of other scientific contributions.To give a more concrete example, the number of downloads that can be seen on the system amounts to a number around 315 indicating that many other researchers are using the data in multitude of ways. More concretely, a quick inspection of the total amount of downloads of these datasets reveal that there are 312 full downloads in total (at the time of writing these lines, and probably lower than the actual amount since HBP system does not

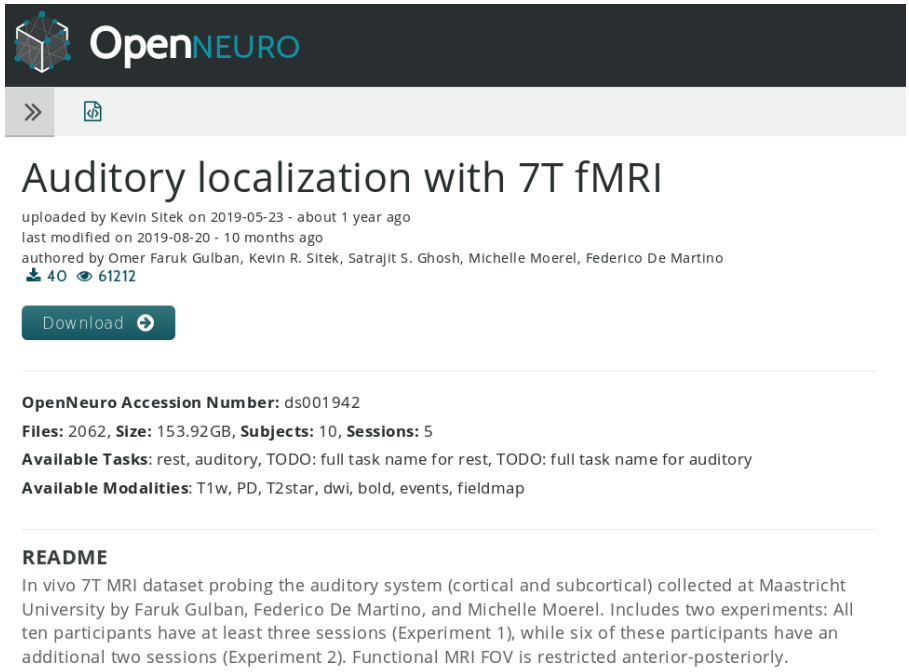

FIGURE V2: Gulban, O. F., Sitek K. R., Ghosh S. S., Moerel M., De Martino F. (2019) Auditory localization with 7T fMRI [Data set]. Openneuro. https://openneuro.org/datasets/ds001942

show the amount of downloads). This number indicates that around 312 other entities benefited, or in the process of benefiting from these datasets in multitude of ways.

Any scientific study is tightly linked to methodological developments. In the modern era, such methodological developments are mostly done using computers by means of developing new algorithms and software. Throughout my thesis, I have wholeheartedly embraced the modern software development and sharing methods. Developing a software is first and foremost benefits the creator. Any future activity that requires the same methodology will be done faster, once the new method is implemented adopting the modern software development techniques. The

FIGURE V3: Gulban, O. F., Goebel, R., Zachlod, D., Mohlberg, H., Amunts, K., De Martino, F. (2020). Cytoarchitectonic areas of human auditory cortex on individual brain surfaces [Data set]. Human Brain Project Neuroinformatics Platform. https://doi.org/10.25493%2FCFBA-S36

additional benefit comes when such new software is shared publicly. In this case, the value benefit of the new software becomes a multiplicative force, increasing its value exponentially with each new user. Throughout my thesis, I have immensely benefited from many public software projects, while making small contributions to them whenever I can. In addition, I have created three public software projects myself. These projects were tightly coupled to my scientific publications. Here, I am going to list these project and highlight their usage metrics (see Figures V4, V5, V6).

The software is shared on Github where users can "star" a repository indicating that they like a project. It can be seen that there are 72 stars in total for these projects. The amount of "stars" can be taken as a conservative indicator of how many people used this program adding value to the work

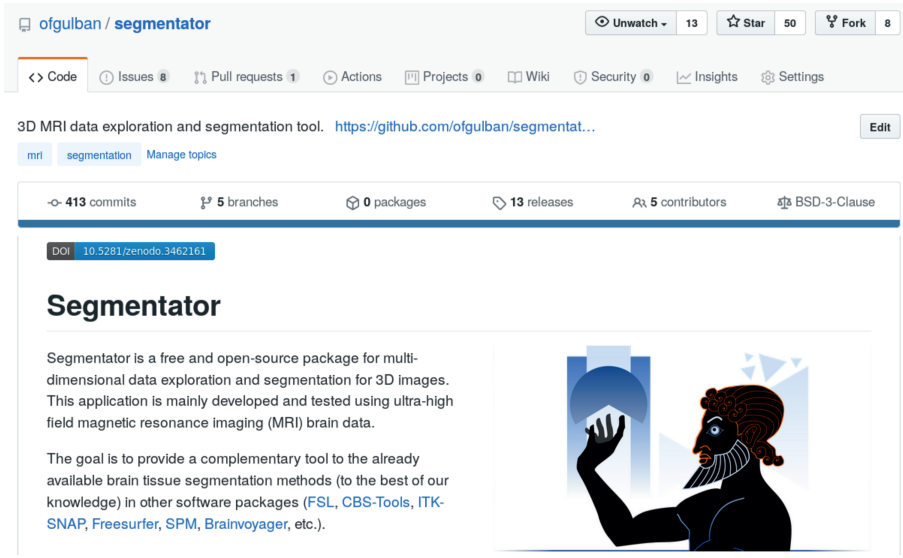

FIGURE V4: Gulban, O. F., Schneider M. (2019, September 26). Segmentator v1.6.0. Zenodo. DOI: http://doi.org/10.5281/zenodo.3462161

presented in this thesis. Which can be understood as these products produced during the analyses performed in this thesis are used by at least 72 other people in some way shape or form. Therefore, the publicly available software directly adds value to this thesis.

As the final words on knowledge valorisation, all chapters of this thesis will be publicly available upon final assessment through the Maastricht University library (most of the published articles and conference contributions are already publicly available in open access journals and other web-based systems that provides digital object identifiers). Considering that the data, software, and scientific articles produced in this thesis are all publicly accessible, there is no doubt that the public money spent on this project Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) VIDI 864-13-012 is guaranteed to return to the public both in the national level and hopefully more so in the international level (see). It is conceivable that new studies will make use of the data, software and the scientific articles to develop new software, acquire newer more ambitious

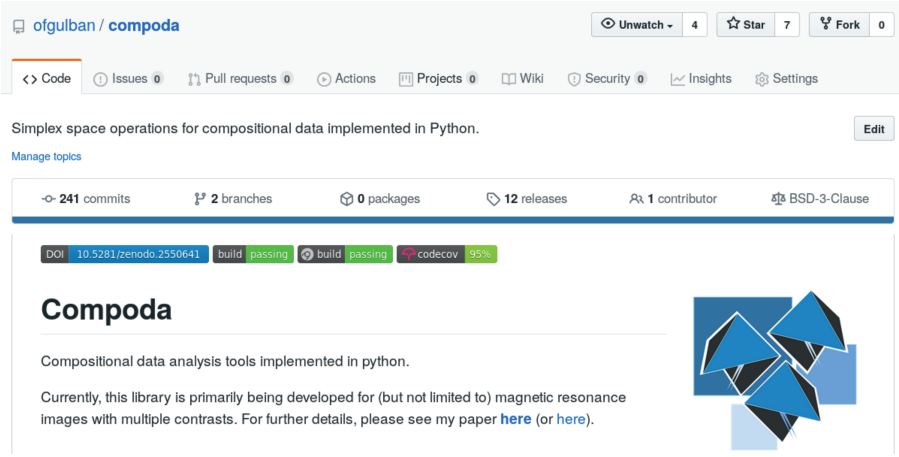

FIGURE V5: Gulban, O. F. (2019, January 27). Compoda v0.3.5. Zenodo. DOI: http://doi.org/10.5281/zenodo.2550641

datasets, communicate and progress the science much further than what is achieved in this thesis.

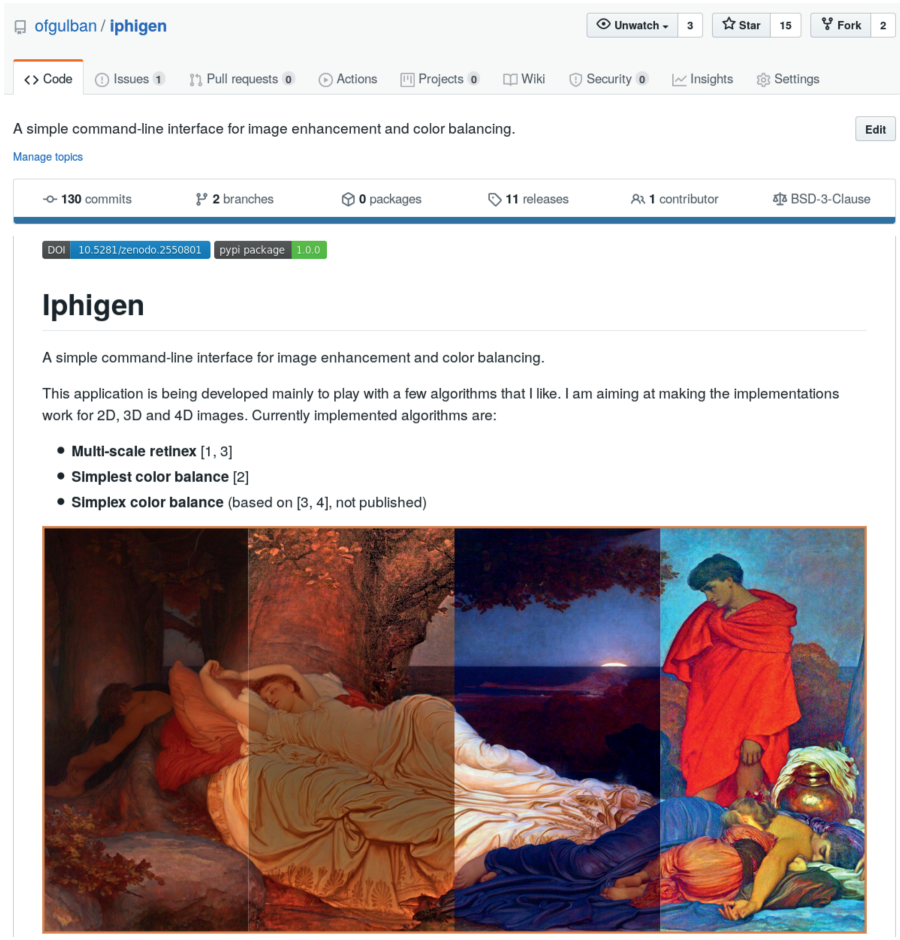

FIGURE V6: Gulban, O. F. (2019, January 27). Iphigen v1.0.0. Zenodo. DOI: http://doi.org/10.5281/zenodo.2550801

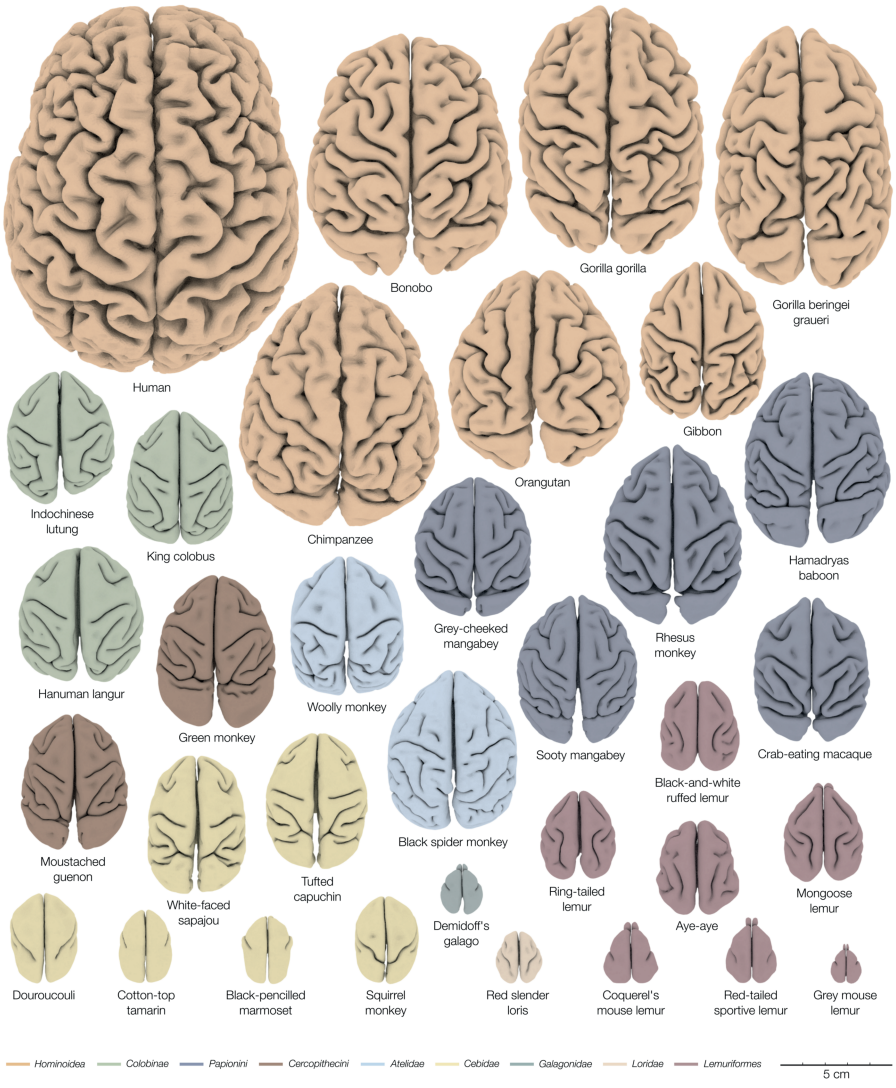

FIGURE V7: Segmentator software developed within the scope of this thesis is already used in a much larger scope in Heuer et al., 2019 where non-human primate brain images are analyzed, image licensed under Creative Commons Attribution 4.0 International Public License.